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Research Article

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Surgical Management of Subtrochanteric Femur Fractures: A Review of Modern Reduction Techniques

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ABSTRACT

Background: Residual rotational instability following isolated Anterior Cruciate Ligament Reconstruction (iACLR) is a critical biomechanical deficit that contributes significantly to graft failure, particularly observed in high-risk patient populations identified across Level I evidence.1 Lateral Extra-articular Tenodesis (LET) has re-emerged as a common, evidence-based method of Anterolateral Structure Augmentation (ASA) to address this specific instability [1].

Purpose: This synthesis critically evaluates the highest-quality evidence, specifically Level I and II data, regarding the efficacy, safety profile, and clinical indications for adding a concomitant LET procedure, or Anterolateral Ligament Reconstruction (ALLR), to both primary and revision ACLR [1].

Methods: Data compiled from recent high-quality meta-analyses and randomized controlled trials (RCTs) were systematically reviewed to quantify outcomes. Key metrics evaluated included structural graft failure rates, rotational stability metrics (specifically the pivot shift phenomenon), Patient-Reported Outcome Measures (PROMs), and overall complication profiles [1].

Results: In the context of primary ACLR, the inclusion of an augmented procedure resulted in a statistically significant reduction in graft rerupture. Specifically, the augmented group was approximately 3 times less likely to experience structural failure compared to the isolated group (Risk Ratio: 0.31, P<.001) [1]. Residual rotatory laxity, the procedure's primary target, was markedly reduced, decreasing the odds of a residual positive pivot shift by 76% (Adjusted OR 0.24) [2]. The benefit is overwhelmingly robust in the revision setting, where augmentation reduced the likelihood of subsequent failure by 56% (Odds Ratio, 0.44; P=.007) [3]. High-risk cohorts, including patients under 25 years and elite pivoting athletes, are consistently identified as the primary beneficiaries of this prophylactic structural stabilization [4,5]. Crucially, the overall complication rate attributed to the adjunct procedure is low (4.2%) and comparable to the typical rates reported for isolated ACLR procedures [6].

Conclusion: The addition of LET is established as an effective, evidence-based surgical adjunct. Its primary clinical role is prophylactic, serving to secure the structural integrity of the intra-articular ACL graft, particularly in patients presenting with high mechanical, anatomical, or demographic risk factors for failure [4,7]. Major orthopedic bodies provide a moderate strength recommendation supporting its use in select patients, particularly those undergoing hamstring autograft reconstruction [7].

Keywords: Lateral Extra-articular Tenodesis, ACLR, LETS, ACL, Knee Instability, Pivot Shift

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Introduction

The fundamental objective in the surgical management of Anterior Cruciate Ligament (ACL) rupture is the restoration of both structural integrity and multi-planar stability to the injured knee joint13. Despite significant advancements and refinements in intra-articular surgical techniques over the past two decades, residual rotational instability remains a substantial clinical challenge. This instability, which classically manifests as a positive pivot shift phenomenon, is consistently identified as a primary driver of unsatisfactory clinical outcomes and catastrophic graft failure following isolated intra-articular ACLR (iACLR) [8-15].

The Role of the Anterolateral Complex in Stability

The knee joint's resistance to multi-planar instability is mediated by the synergistic interaction between the central ACL and the Anterolateral Complex (ALC) of the knee [14]. The ALC, which includes the Anterolateral Ligament (ALL) and the Iliotibial Band (ITB), functions to provide critical rotational control, particularly during dynamic cutting and pivoting maneuvers. When these anterolateral structures are concomitantly injured—an occurrence frequently associated with high-grade rotational laxity—an isolated intra-articular reconstruction is often insufficient to restore native kinematics [15].

Resurgence of Anterolateral Augmentation

The recognition of the ALC's importance has led to a significant resurgence of anterolateral augmentation techniques aimed at performing an extra-articular stabilization procedure^{15}. Lateral Extra-articular Tenodesis (LET), utilizing a defined strip of the Iliotibial Band (ITB), has emerged as the most common and robust modality used to supplement the intra-articular ACL reconstruction [16]. The central objective of performing LET is to directly address Anterolateral Rotatory Instability (ALRI) and, through mechanical offloading, substantially decrease the damaging strain placed upon the intra-articular ACL graft during the critical early healing and remodeling phases [17].

Rationale for Synthesis and Review

The body of evidence supporting anterolateral augmentation has grown rapidly in both volume and quality, providing high-level quantitative data demonstrating the efficacy of LET in mitigating structural failure and improving stability in both primary and revision ACLR settings. The purpose of this synthesis is to consolidate this data, focusing on the most rigorous Level I and II evidence, to provide clear clinical guidance on patient selection and anticipated outcomes. By linking the clinical presentation (high-grade pivot shift) to the anatomical deficiency (ALC injury) and the mechanical solution (LET), the necessity of a risk-stratified approach to ACL reconstruction is underscored.

Materials and Methods

Biomechanical Rationale

The demonstrated clinical efficacy of the LET procedure is fundamentally rooted in its mechanical ability to constrain pathological internal rotation of the tibia relative to the femur14. The procedure is designed to act as either a static or dynamic restraint on the lateral aspect of the knee, thereby directly reducing excess tibial rotation, which is critical for stabilizing the knee during the high-demand athletic maneuvers that often lead to graft failure [18-20].

A thorough understanding of this mechanism confirms that the procedure's value lies in managing forces that an isolated ACL graft cannot effectively withstand. By controlling this excessive rotation, the procedure limits the damaging shear and rotational strains imposed on the intra-articular ACL graft. This mechanical offloading is critical, as it promotes superior graft healing and maturation while simultaneously reducing the peak mechanical stresses that drive graft failure, leading to a significantly lower rate of re-rupture [20,21]. Biomechanical studies further confirm that precise technical execution is paramount for optimizing function; proper tensioning of the graft, particularly when applied at approximately 300 of flexion, is critical to achieving the optimal balance between rotational and sagittal stability, preventing over-constriction while maximizing rotatory control [14,22]. The robust statistical success (e.g., RR 0.31) observed in clinical trials hinges entirely upon the correct application of these biomechanical principles.

Common Surgical Technique

The most frequently employed and standardized method for performing LET is the Modified Lemaire Technique^{10, 23}. This procedure typically involves harvesting a defined strip of the Iliotibial Band (ITB), frequently measuring approximately 8 X 1 centimeter[10,23,24].

The graft is left anchored distally at Gerdy's tubercle, maintaining its vascular and mechanical integrity distally. It is then released proximally from the vastus lateralis and subsequently routed deep, passing underneath the Lateral Collateral Ligament (LCL) [10,25]. The technical endpoint involves securing the graft to the femur at a specific point just proximal and posterior to the lateral epicondyle [25]. Contemporary techniques emphasize the use of low-profile fixation devices, such as knotless anchors, which are designed to standardize tensioning and fixation. The adoption of these devices helps to minimize hardware prominence, which can cause patient discomfort, and mitigates the risk of tunnel convergence and related hardware complications, thereby ensuring that the procedure's biomechanical benefits are achieved with minimal surgical morbidity [10].

Results

Synthesis of Efficacy Data Level I randomized controlled trials (RCTs) consistently report superior structural outcomes when an anterolateral procedure is added concomitantly to primary ACLR compared to isolated reconstruction alone [1].

Primary ACLR: Graft Failure and Stability

The primary and most impactful clinical advantage conferred by the addition of LET is the profound reduction in the risk of graft rerupture, which represents the most catastrophic failure mode in ACL surgery.

Structural Outcomes

Meta-analyses demonstrate that patients undergoing ACLR with concomitant LET are approximately 3 times less likely to experience structural graft failure compared to those treated with isolated ACLR alone. This effect is highly statistically significant, reflected by a Risk Ratio (RR) of 0.31 (95% CI, 0.17 to 0.58; $P<.001$), strongly favoring the augmented group [1]. Similarly, meta-analyses focusing specifically on combined ACL and ALL reconstruction groups have also shown a significantly lower rate of graft failure compared to isolated ACLR (Odds Ratio, 0.37; P=.008) [24].

The robust nature of this protection is further illustrated by graft survival rates. At 24 months post-surgery, Kaplan–Meier survival rates were 95.7% for the ACLR + LET group, a significantly higher rate than the 82.6% observed for isolated ACLR [2]. This difference yields an Absolute Risk Reduction (ARR) of 13%, quantifying the substantial clinical benefit. This translates to a highly favorable Number-Needed-to-Treat (NNT) of only 8 patients to prevent one structural graft failure [2]. This NNT of 8 represents a strong threshold for adopting the procedure in high-risk patient subgroups.

Rotational and Sagittal Stability

The procedure achieves its structural protection primarily through rotational control. The combined procedure significantly reduces the prevalence of a residual positive pivot shift (defined as Grade 1 or higher), which is the clinical manifestation of Anterolateral Rotatory Instability (ALRI). LET reduced the odds of residual rotatory laxity by 76%, a statistically powerful finding (Adjusted OR 0.24; 95% CI, 0.09 to 0.65; P= 0.004) [2].

In contrast, instrumented measurements of anterior translation, such as the KT-1000, which quantify sagittal laxity (side-to-side difference), often demonstrate non-significant differences between augmented and isolated groups in primary ACLR [13]. This distinction confirms that the essential role of LET is specific rotational constraint rather than increasing stiffness in anterior tibial translation, thereby maintaining desirable kinematics while securing the intra-articular graft against twisting forces.

The key quantitative findings regarding primary ACLR efficacy are summarized in Table 1.

Table 1: Meta-Analysis Synthesis of Primary ACLR Efficacy

Outcome Metric	Comparison	Quantitative Finding	Statistical Measure	P-Value/ Significance	Source
Graft Failure Rate	ACLR + LET vs. Isolated ACLR	3 times less likely	Risk Ratio (RR): 0.31 (95% CI, 0.17–0.58)	P<.001	1
Graft Survival (24 Months)	ACLR + LET vs. Isolated ACLR	95.7% vs. 82.6% (13.0% ARR)	Kaplan–Meier Curve	P= 0.046	2
Residual Pivot Shift (Grade 1+)	ACLR + LET vs. Isolated ACLR	Reduced odds by 76%	Adjusted OR: 0.24 (95% CI, 0.09–0.65)	P= 0.004	2
IKDC Score Improvement	ACLR + LET vs. Isolated ACLR	Statistically superior outcome	Mean Difference (MD): 2.31	P= 0.01	1
RTS Rate	Combined ACL/ALL vs. Isolated ACLR	Higher rate	OR: 1.41 (95% CI, 1.11–1.80)	P=.005	15

Revision ACLR and High-Risk Cohorts

The benefits of anterolateral augmentation are most quantitatively robust and clinically compelling in the revision surgery setting, a scenario where re-rupture rates for isolated revision ACLR (iACLR) are historically elevated due to compromised native tissue and bone stock. Systematic reviews consistently confirm that augmented revision ACLR (aACLR) provides outcomes significantly superior to those achieved with isolated revision ACLR [3,21].

Revision Surgery Efficacy

For revision procedures, the augmented group was 56% less likely to experience a subsequent failure (OR, 0.44; 95% CI, 0.24 to 0.80; P=.007) [3]. This magnitude of failure reduction firmly supports the routine use of augmentation in complex revision cases. Furthermore, the procedure restored superior rotational stability (OR, 2.77; P<.00001), resulting in a 68% relative risk reduction for possessing a high-grade (Grade 2 or 3) pivot shift compared to iACLR [3]. Functional superiority was also more pronounced in aACLR, particularly for patients presenting with high-grade pre-existing laxity (defined as Grade 2) [3].

High-Risk Subgroups

Patient selection should focus on those subgroups identified as carrying an inherently higher risk of failure. Patients under 25 years of age are frequently cited in the literature as a high-risk demographic due to their high exposure to rotational stress and biological factors contributing to early graft failure [5]. Subgroup analysis specific to patients under 19 years old found a 61% lower graft rupture rate when a combined procedure was used (RR 0.39) [5,17]. Furthermore, elite pivoting athletes, who regularly subject their knees to extreme rotational forces, also represent a high-risk cohort where augmentation is strongly indicated [4].

The quantitative superior results for revision ACLR, where mechanical protection is arguably most vital, are summarized in Table 2.

Table 2: Quantitative Benefits of Augmentation in Revision ACLR (aACLR vs. iACLR)

Outcome Metric	Comparison Group	Quantitative Finding	Statistical Measure	P-Value/ Significance	Source
Failure Rate	aACLR vs. iACLR	56% less likely to fail	Odds Ratio (OR): 0.44 (95% CI, 0.24 to 0.80)	P= 0.007	3
Rotational Stability	aACLR vs. iACLR	Superior stability	Odds Ratio (OR): 2.77 (95% CI, 1.91 to 4.01)	P<.00001	3

Side-to-Side Difference (SSD)	aACLR vs. iACLR	Lower difference	OR: -0.53 (95% CI, -0.81 to -0.24)	P= 0.0003	3
IKDC Score (High Laxity Group)	aACLR vs. iACLR	Greater score superiority	SMD: 0.51 (95% CI, 0.16 to 0.86)	P= 0.005	3
RTS Rate	Combined ACL/ALL vs. Isolated ACLR	Higher rate	OR: 1.41 (95% CI, 1.11–1.80)	P=.005	15

Discussion

Clinical Indications and High-Risk Factors

The decision to incorporate anterolateral augmentation must be guided by a stratified assessment of specific clinical, anatomical, and activity-related risk factors for graft failure. Universal adoption is not supported by the evidence; rather, a targeted approach ensures maximum benefit where the risk of primary failure is highest.

Key established criteria supporting the use of LET augmentation include:

- **Age and Activity:** Patients under 25 years and those engaged in high-level, elite pivoting sports (e.g., soccer, basketball) [4]. These cohorts face high exposure to rotational forces, which historically correlates with higher graft failure rates.
- **Knee Laxity:** Pre-existing high-grade pivot shift (Grade 2 or 3) is a direct clinical sign of uncontrolled Anterolateral Rotatory Instability (ALRI). Since the primary function of LET is to address this specific deficit, its use is strongly supported in these cases [3]. Patients with inherent generalized ligamentous laxity are also included in this group [4].
- **Surgical Status:** Revision ACLR surgery represents a major indication. The substantial statistical superiority demonstrated by augmented procedures in this scenario means augmentation approaches the standard of care due to the typically compromised condition of the knee post-failure [3].
- **Anatomical Factors:** Increased posterior tibial slope (PTS 120) is recognized as a significant anatomical risk factor that dramatically increases the shear force placed on the intra-articular ACL graft [11]. The addition of an extra-articular mechanical restraint is necessary to offload this damaging force and stabilize the knee against biomechanical malalignment [11].
- **Graft Specificity:** The American Academy of Orthopaedic Surgeons (AAOS) provides a moderate strength recommendation specifically linking augmentation to concomitant hamstring (HT) autograft use in select patients [7,22,23].

The synthesis of these factors provides actionable thresholds for patient selection, as summarized in Table 3.

Table 3: High-Risk Clinical Indications and Anatomical Thresholds for LET Augmentation

Risk Factor Category	Specific Indication/Threshold	Clinical Rationale & Consensus	Source
Age & Activity	Patients under 25 years; Elite/ Pivoting Athletes (e.g., soccer)	High exposure to rotational forces and historically high graft failure rates in young, active cohorts.	4
Knee Laxity	High-grade Pivot Shift (Grade 2 or 3); Inherent Ligamentous Laxity	Direct evidence of uncontrolled ALRI; primary function of LET is addressing this deficit.	3
Surgical Status	Revision ACLR surgery	Augmented procedures are statistically superior, approaching standard-of-care due to compromised knee status.	3
Anatomical Risk	Increased Posterior Tibial Slope (PTS 120)	Anatomical risk factor that increases shear force on the ACL graft, necessitating extra-articular mechanical offloading.	11
Graft Specificity	Concomitant Hamstring (HT) Autograft Use	AAOS moderate recommendation specifically links augmentation to HT grafts in select patients.	7

Functional Outcomes and Return to Sport (RTS)

While the mechanical gains delivered by LET are profound, the corresponding improvements in Patient-Reported Outcome Measures (PROMs) are often statistically significant but clinically modest, particularly in the short term following primary ACLR25. The modest absolute functional gain reported by patients (Mean Difference of 2–3 points on scales like IKDC) contrasts sharply with the substantial failure risk reduction (approximately 70% reduction in odds) [1,2]. This observation confirms a fundamental understanding of the procedure: the primary clinical value of LET is structural preservation and long-term graft protection rather than a dramatic short-term symptomatic improvement or functional restoration beyond what is provided by the intra-articular graft alone. LET is fundamentally a prophylactic structural procedure [4].

However, the benefits extend significantly to measures of recovery and performance exposure. Combined ACL/ALL reconstruction has been associated with a statistically significant higher rate of successful Return to Sport (RTS) compared to isolated ACLR (OR, 1.41; P=.005) [15]. In the critical population of elite athletes, the addition of LET reduced the re-tear rate from 9.5% in the isolated ACLR group to 3.4% in the combined group, effectively reducing the risk of graft failure by a factor of 2.8 [5]. This suggests that the improved mechanical stability may increase patient and clinician confidence, allowing for a safer and potentially faster return to high-level competition, thereby impacting career-defining outcomes.

Safety Profile and Complications

A major historical concern regarding extra-articular procedures was the potential for increased knee stiffness or accelerated osteoarthritis due to over-constraint. However, contemporary systematic reviews, focusing on anatomically optimized techniques such as the Modified Lemaire, consistently conclude that the procedure is safe, with manageable risks that do not compromise overall outcomes [6].

Morbidity Parity

The addition of an anterolateral procedure does not significantly increase the overall perioperative risk profile compared to isolated ACLR6. The total complication rate specifically attributed to the LET procedure was consistently reported to be approximately 4.2%, a rate comparable to the typical perioperative complication rate reported for isolated ACLR (approximately 4.3%)6. This parity in morbidity confirms that the substantial benefit in structural integrity is achieved without undue surgical cost or risk to the patient.

Specific and Mitigated Risks

Specific risks associated with the technique include chronic lateral pain or discomfort over the dissection site, although this is usually manageable. Peroneal nerve palsy remains a recognized, though infrequent, complication that necessitates careful surgical execution6. Crucially, historical concerns regarding stiffness have been largely mitigated; contemporary studies have generally not shown an increased rate of clinically significant knee stiffness or progression to osteoarthritis compared to isolated ACLR, suggesting that proper tensioning and anatomical fixation, as outlined in the methods section, have successfully overcome this long-standing clinical challenge. This outcome is a validation of the technical evolution of the procedure, where success is conditional upon adherence to standardized, biomechanically guided protocols [14,22].

Integration into Clinical Guidance

The robust and growing body of high-quality evidence supporting anterolateral augmentation has led to its formal inclusion in major clinical guidelines globally. The AAOS provides a Moderate Strength Recommendation stating that ALL reconstruction or LET should be considered in select patients when performing a hamstring autograft reconstruction7,23. Furthermore, the ESSKA consensus strongly supports the integration of the procedure in the revision setting, given the superior outcomes documented in the literature for this high-risk population [12,23].

The overwhelming statistical evidence showing superior structural protection in specific high-risk cohorts—those under 25, patients with high-grade pivot shift, and revision cases—confirms that the decision to augment is now a critical element of risk management in modern ACL surgery.

Conclusion

The meta-analytical evidence rigorously affirms that Lateral Extra-articular Tenodesis (LET) or Anterolateral Ligament Reconstruction (ALLR) is a highly effective surgical adjunct, particularly indicated for patients identified as carrying high mechanical, anatomical, or demographic risk factors for structural graft failure. The procedure significantly improves structural integrity by markedly reducing rotational laxity (Pivot Shift OR 0.24) and minimizing the incidence of catastrophic re-rupture (RR 0.31) [1,2]. The evidence confirms that augmentation is primarily a prophylactic structural procedure, designed to offload the intra-articular graft and ensure long-term stability and graft survival. Given the demonstrated safety profile, the application of LET should move toward a risk-stratified, standard surgical approach in carefully selected populations, particularly in revision surgery where its efficacy is most pronounced [24,25].

Future Directions

Despite the established efficacy, continued research is necessary in several key areas. High-quality research is required to refine surgical techniques for the skeletally immature patient, focusing on procedures that minimize the risk of growth disturbance while providing necessary stability18. Furthermore, long-term (10- to 20-year) follow-up data are essential to definitively confirm that the augmented rotational constraint achieved by modern techniques does not, over decades, contribute to premature degenerative joint changes or knee osteoarthritis.

Declarations

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Conflict of Interest

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